INTER-COMPARISON OF FORWARD RADIATIVE TRANSFER COMPUTER MODELS

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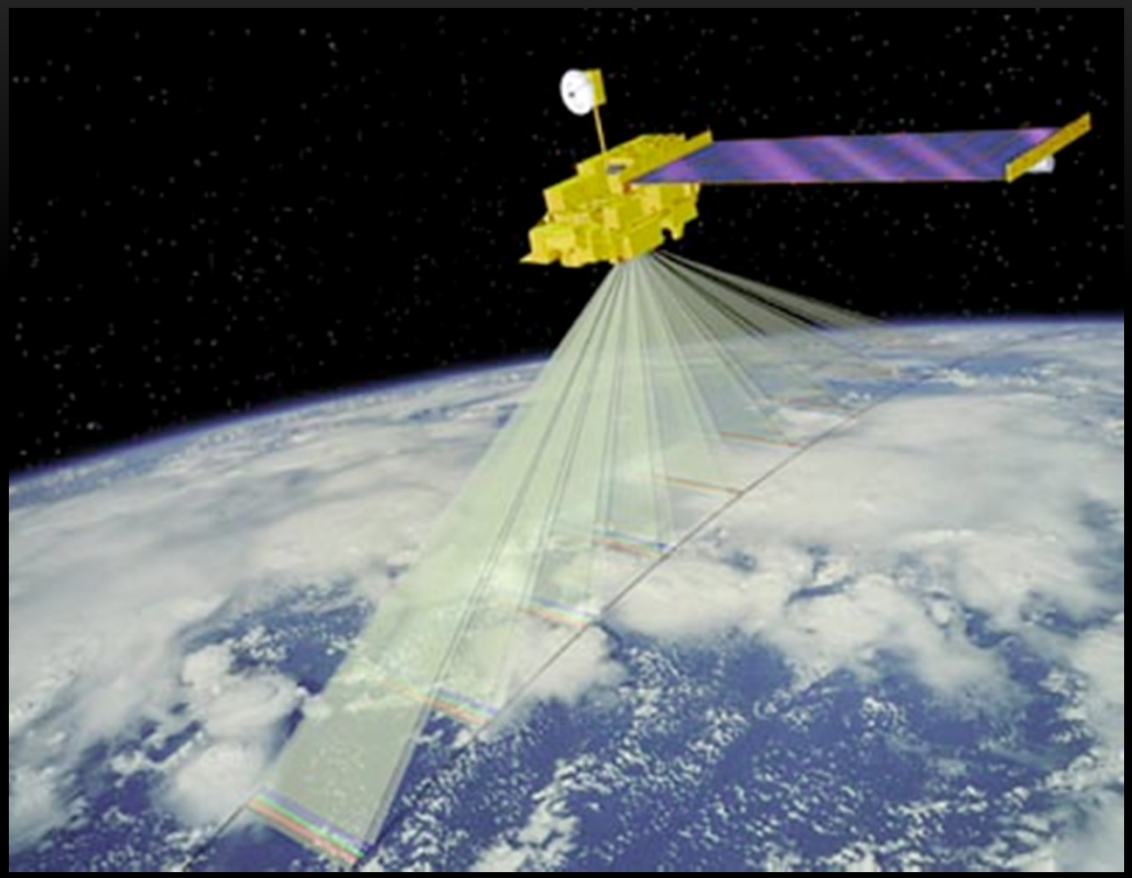
MULTI-ANGLE IMAGING SPECTRO-RADIOMETER (MISR)



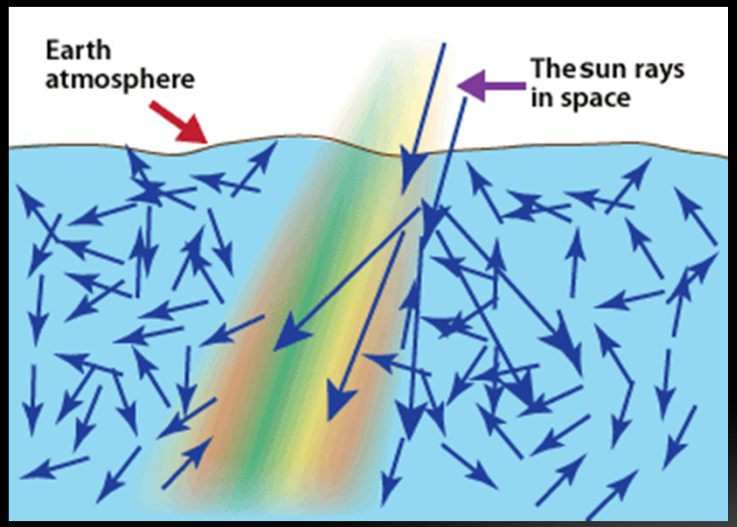
- The amount and type of atmospheric particles (aerosols), including those formed by natural sources and by human activities
- The amounts, types, and heights of clouds
- Estimation of the total amount of sunlight reflected.

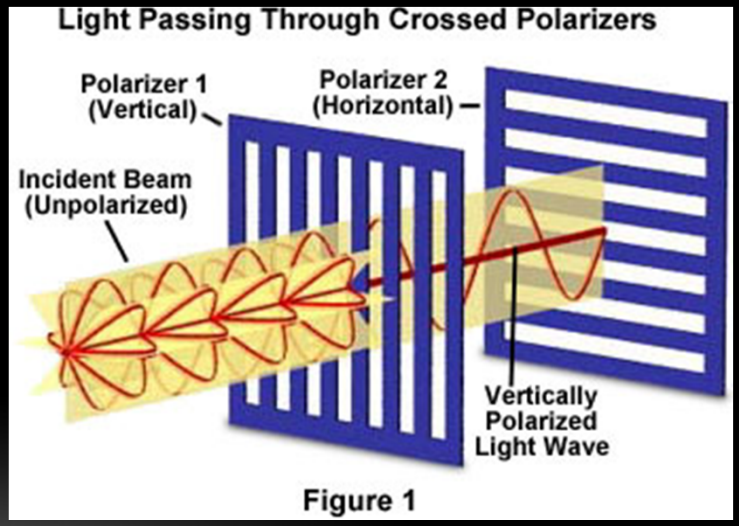
VOCABULARY

Radiances: are measures of the quantity of radiation

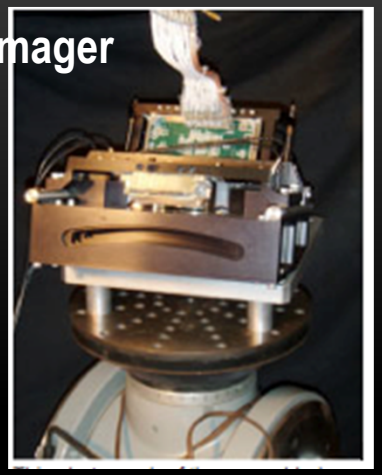
Polarization: is a property of waves that can oscillate with more than one orientation

Rayleigh Scattering: is the scattering of light by particles much smaller than the wavelength of the light





Airborne Multi-angle Spectro-Polarimeter Imager

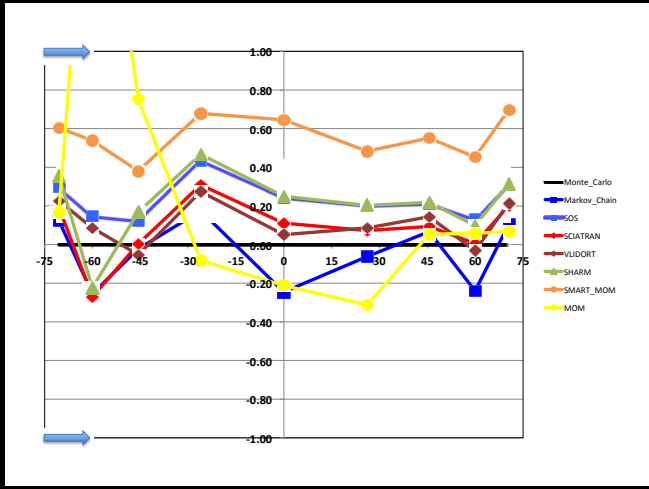


BACKGROUND

- **Motivation:** Future instrumentation accuracies
  - Radiances: 1.5 – 2%
  - Degree of Linear Polarization (DOLP): 0.005 or better
- **Goal:**
  - Radiative transfer models are used to predict measured signals
  - The computer models need to better than those accuracies
  - 8 different computer models (codes) will be compared
- **Without Polarization:** Do radiances agree within 1%?
- **With Polarization:** Do DOLPs agree within 0.002?

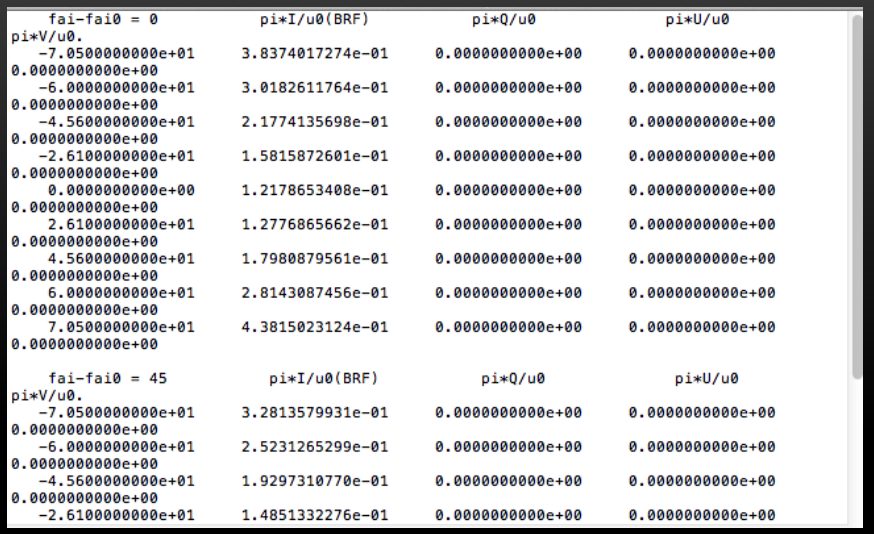
MY PROJECT

- Develop the data base
- Produce a preliminary set of graphs
- Begin an inter-comparison analysis
- Verify that models agree within the desired accuracy goals



METHODOLOGY

- Create fluid database
- Text to Excel data
- Transfer Data to Database
- Send data to Modelers to confirm their numbers
- Create preliminary plots as an analytical tool
- “Z score” analysis



fai-fai0 = 0	pi*I/u0(BRF)	pi*Q/u0	pi*U/u0	pi*V/u0.
-7.0500000000e+01	3.8374017274e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
-6.0000000000e+01	3.0182611764e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
-4.5600000000e+01	2.1774135698e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
-2.6100000000e+01	1.5815872601e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
0.0000000000e+00	1.2178653408e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
2.6100000000e+01	1.2776865662e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
4.5600000000e+01	1.7980879561e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
6.0000000000e+01	2.8143087456e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
7.0500000000e+01	4.3815023124e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
fai-fai0 = 45	pi*I/u0(BRF)	pi*Q/u0	pi*U/u0	pi*V/u0.
-7.0500000000e+01	3.2813579931e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
-6.0000000000e+01	2.5231265299e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
-4.5600000000e+01	1.9297310770e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00
-2.6100000000e+01	1.4851332276e-01	0.0000000000e+00	0.0000000000e+00	0.0000000000e+00

	A	B	C	D	E	F	G	H
1		fai-fai0	=	0	pi*I/u0(BRF)	pi*Q/u0	pi*U/u0	pi*V/u0.
2		-7.05E+01	3.84E-01	0.00E+00	0.00E+00	0.00E+00		
3		-6.00E+01	3.02E-01	0.00E+00	0.00E+00	0.00E+00		
4		-4.56E+01	2.18E-01	0.00E+00	0.00E+00	0.00E+00		
5		-2.61E+01	1.58E-01	0.00E+00	0.00E+00	0.00E+00		
6		0.00E+00	1.22E-01	0.00E+00	0.00E+00	0.00E+00		
7		2.61E+01	1.28E-01	0.00E+00	0.00E+00	0.00E+00		
8		4.56E+01	1.80E-01	0.00E+00	0.00E+00	0.00E+00		
9		6.00E+01	2.81E-01	0.00E+00	0.00E+00	0.00E+00		
10		7.05E+01	4.38E-01	0.00E+00	0.00E+00	0.00E+00		
11								
12		fai-fai0	=	45	pi*I/u0(BRF)	pi*Q/u0	pi*U/u0	pi*V/u0.
13		-7.05E+01	3.28E-01	0.00E+00	0.00E+00	0.00E+00		
14		-6.00E+01	2.52E-01	0.00E+00	0.00E+00	0.00E+00		
15		-4.56E+01	1.93E-01	0.00E+00	0.00E+00	0.00E+00		
16		-2.61E+01	1.49E-01	0.00E+00	0.00E+00	0.00E+00		
17		0.00E+00	1.22E-01	0.00E+00	0.00E+00	0.00E+00		
18		2.61E+01	1.27E-01	0.00E+00	0.00E+00	0.00E+00		
19		4.56E+01	1.65E-01	0.00E+00	0.00E+00	0.00E+00		
20		6.00E+01	2.36E-01	0.00E+00	0.00E+00	0.00E+00		
21		7.05E+01	3.35E-01	0.00E+00	0.00E+00	0.00E+00		
22								

COMPUTER MODELS

Monte Carlo (A. Davis Reference model)	JPL
Markov Chain (F. Xu)	JPL
SOS (P Zhai (mixed), M. J. Garay (pure))	Developed at NASA's Langley Research Center (LaRC) by P. Zhai, used at JPL by M. Garay.
SCIATRAN (A. A. Kokhanovsky)	Developed at Bremen University, Institute for Environmental Physics, by V. Rozanov, used there by A. Kokhanovsky
VILIDORT (V. Natraj)	Developed by R. Spurr (RT Solutions) JPL by V. Natraj
SHARM (S. V. Korkin)	Developed at NASA's Godard Space Flight Center (GSFC)
MOM (J. V. Martonchik)	JPL
Smart MOM (S. Sanghavi)	JPL

DATA BASE

Angles:
-70.5 -60 -45.6 -26.1 0 26.1 45.6 60 70.5

Inter Comparison Exercise

Phase 1

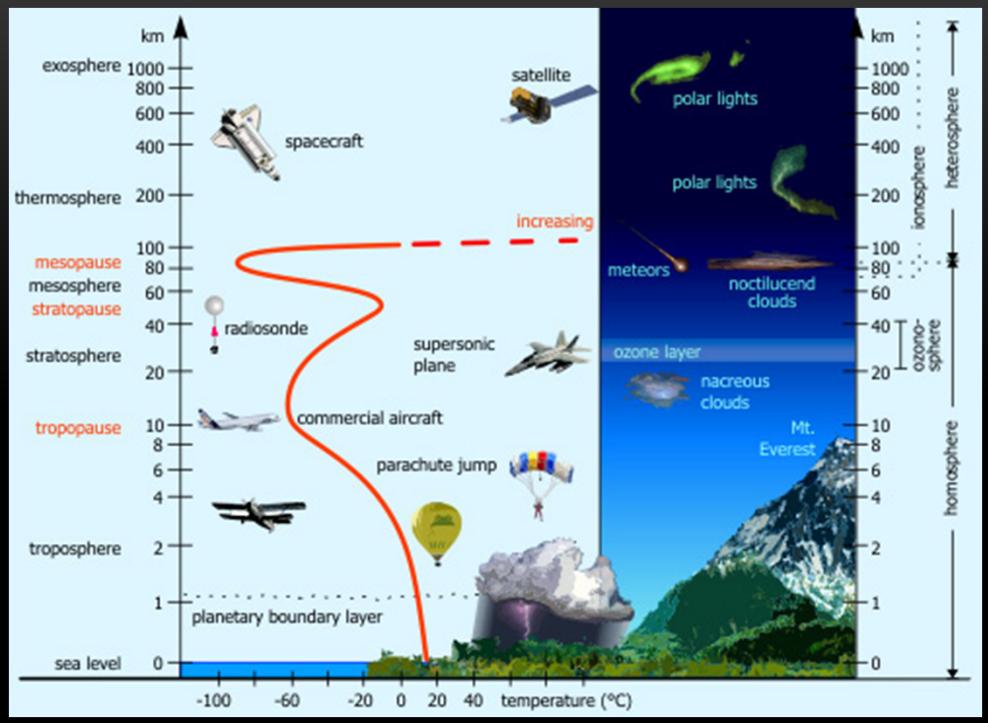
Jargon for w/ and w/o polarization → **Scalar/ Vector**

- **Pure Cases**
  - Rayleigh
  - Dust
  - Smoke
  - Salt
- **Mixed-Cases**

0-2 km	3-5 km
Low	Low
Med	Med
High	High

← height of the aerosol layer

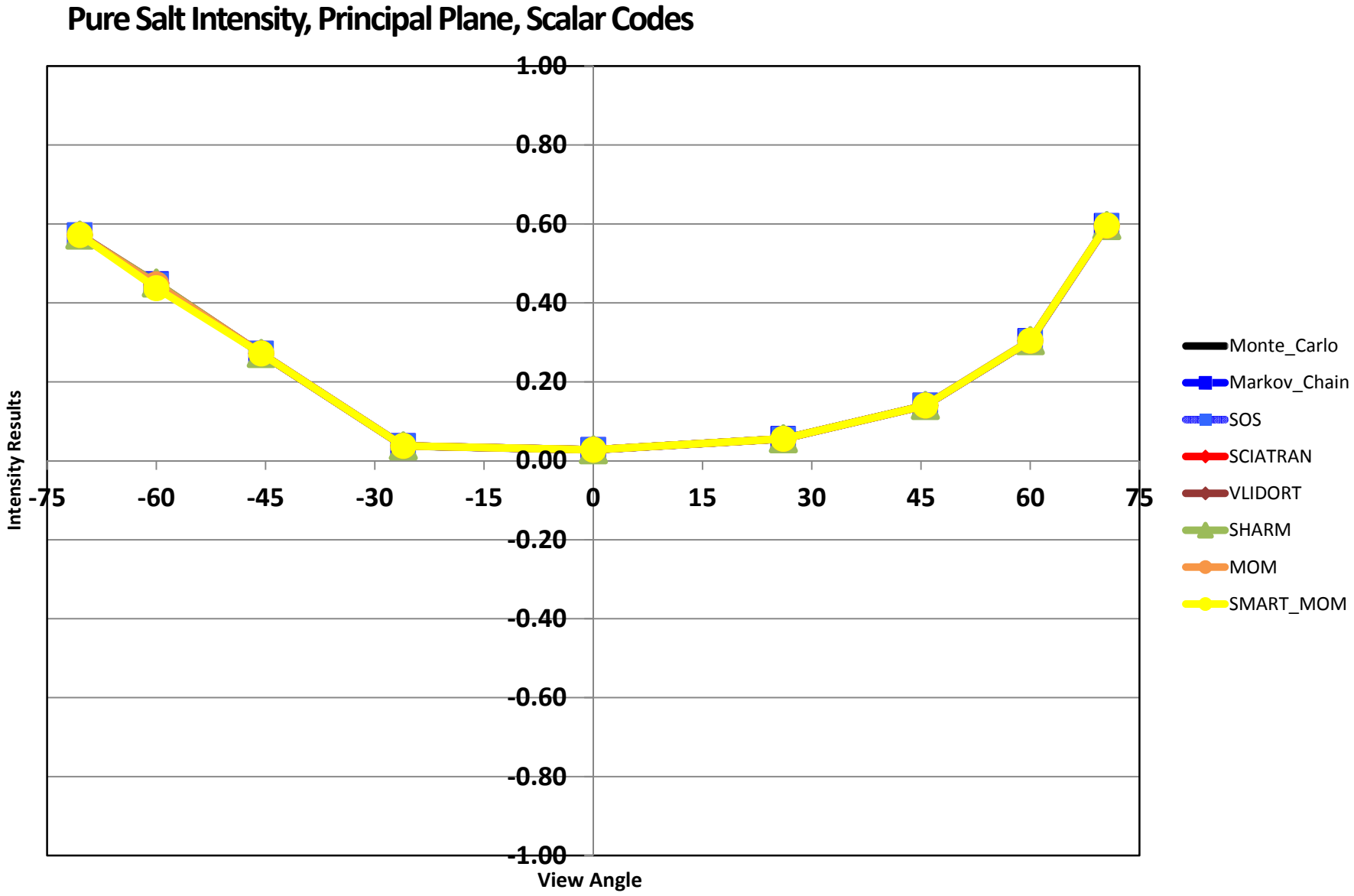
describes the total amount of Rayleigh scattering (respectively: Infra-Red, blue and UV light)

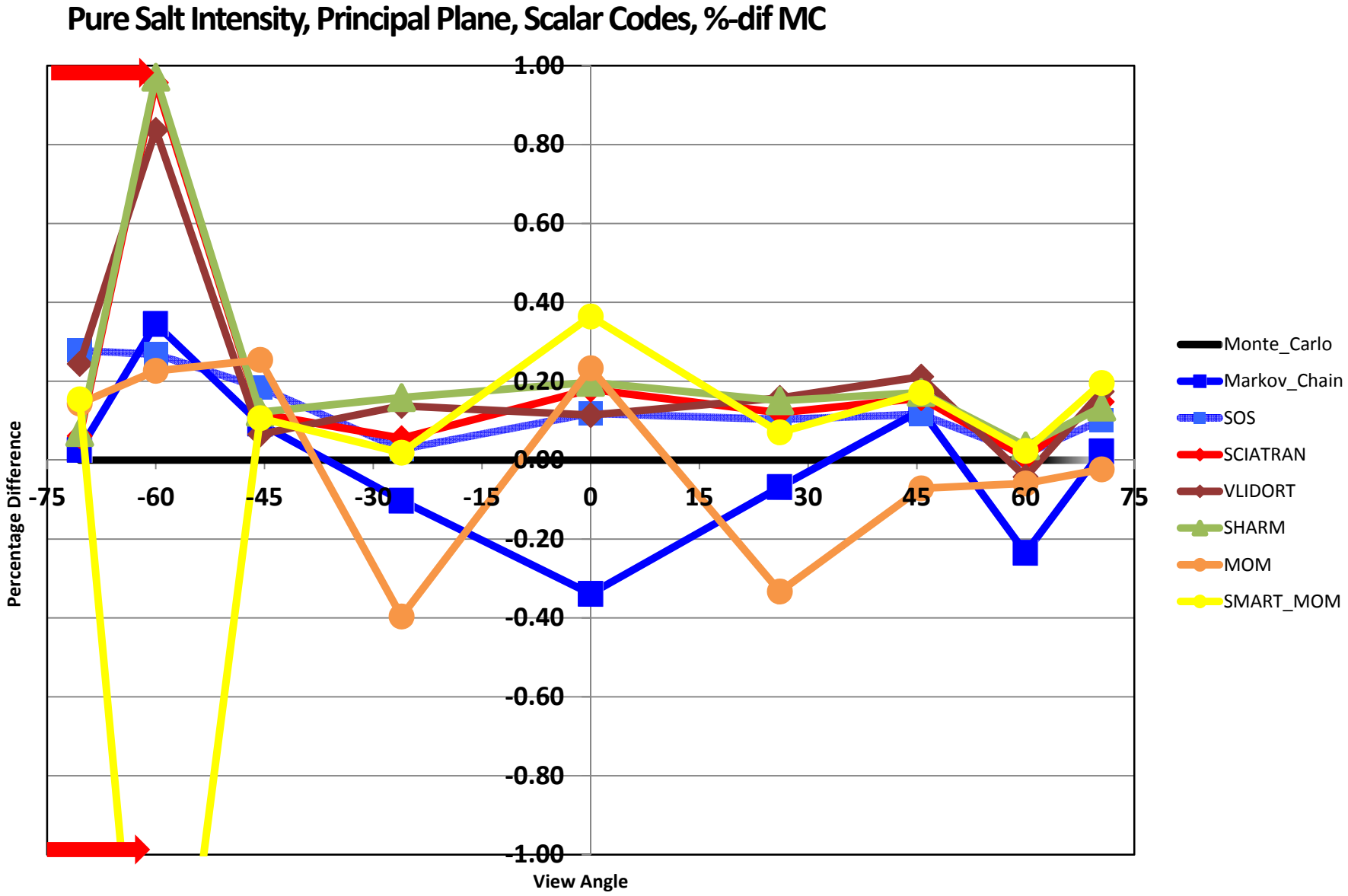


MarkovChain MonteCarlo SCIATRAN SHARM SOS MOM SmartMOM VLIDORT

DATABASE

	A	B	C	D	E	F	G	H	I
1	**JPL Code Intercomparison, Scalar**								
2	**Phase 1, Pure Cases, Dust**								
3									
4									
5	**Dust - Principal Plane**								
6	**Theta**	**Monte_Carlo**	**Markov_Chair**	**SOS**	**SCIATRAN**	**VLIDORT**	**SHARM**	**MOM**	**SMART_MOM**
7	-70.5	0.06869	0.06877	0.06889	0.06882	0.06884	0.06893	0.06880	0.06910
8	-60	0.06662	0.06645	0.06672	0.06644	0.06668	0.06647	0.06822	0.06698
9	-45.6	0.03581	0.03580	0.03585	0.03581	0.03579	3.59E-02	0.03608	0.03595
10	-26.1	0.02552	0.02557	0.02563	0.02560	0.02559	2.56E-02	0.02550	0.02569
11	0	0.02604	0.02597	0.02610	0.02606	0.02605	2.61E-02	0.02598	0.02620
12	26.1	0.03880	0.03878	0.03888	0.03883	0.03883	3.89E-02	0.03868	0.03899
13	45.6	0.07274	0.07279	0.07290	0.07281	0.07285	7.29E-02	0.07278	0.07314
14	60	0.15161	0.15125	0.15181	0.15162	0.15156	1.52E-01	0.15170	0.15230
15	70.5	0.31139	0.31171	0.31236	0.31202	0.31206	0.31237	0.31160	0.31356
16									
17	**Dust - Principal Plane (Delta Monte Carlo%)**								
18	**Theta**	**Monte_Carlo**	**Markov_Chair**	**SOS**	**SCIATRAN**	**VLIDORT**	**SHARM**	**MOM**	**SMART_MOM**
19	-70.5	0.00000	0.12434	0.29631	0.19364	0.22679	0.35670	0.16743	0.60508
20	-60	0.00000	-0.25463	0.14804	-0.27169	0.08612	-0.22366	2.40322	0.53828
21	-45.6	0.00000	-0.02219	0.12466	0.00279	-0.05240	0.16755	0.75398	0.38062
22	-26.1	0.00000	0.17441	0.43290	0.30955	0.27393	0.46628	-0.08229	0.67905
23	0	0.00000	-0.24486	0.24329	0.11139	0.05139	0.24966	-0.21125	0.64490
24	26.1	0.00000	-0.06250	0.20345	0.07216	0.08636	0.20360	-0.31185	0.48401
25	45.6	0.00000	0.06618	0.21289	0.09348	0.14474	0.21858	0.05361	0.55113
26	60	0.00000	-0.23859	0.13223	0.00660	-0.03144	0.09894	0.05936	0.45248
27	70.5	0.00000	0.10416	0.31035	0.20232	0.21441	0.31472	0.06744	0.69752


Pure Salt Intensity, Principal Plane, Scalar Codes
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
-75
-60
-45
-30
-15
0
15
30
45
60
75
Intensity Results
View Angle
Monte_Carlo
Markov_Chain
SOS
SCIATRAN
VLIDORT
SHARM
MOM
SMART_MOM


Pure Salt Intensity, Principal Plane, Scalar Codes, %-dif MC
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
-75
-60
-45
-30
-15
0
15
30
45
60
75
Percentage Difference
View Angle
Monte_Carlo
Markov_Chain
SOS
SCIATRAN
VLIDORT
SHARM
MOM
SMART_MOM

Z SCORE

	Monte_Carlo	Markov_Cha	SOS	SCIATRAN	VLIDORT	APC
Monte_Carlo	0.00	0.56	0.22	2.48	0.34	1.22
Markov_Cha	0.56	0.00	0.69	2.12	0.88	1.59
SOS	0.22	0.69	0.00	2.27	0.52	1.44
SCIATRAN	2.48	2.12	2.27	0.00	2.73	3.70
VLIDORT	0.34	0.88	0.52	2.73	0.00	0.98
APC	1.22	1.59	1.44	3.70	0.98	0.00

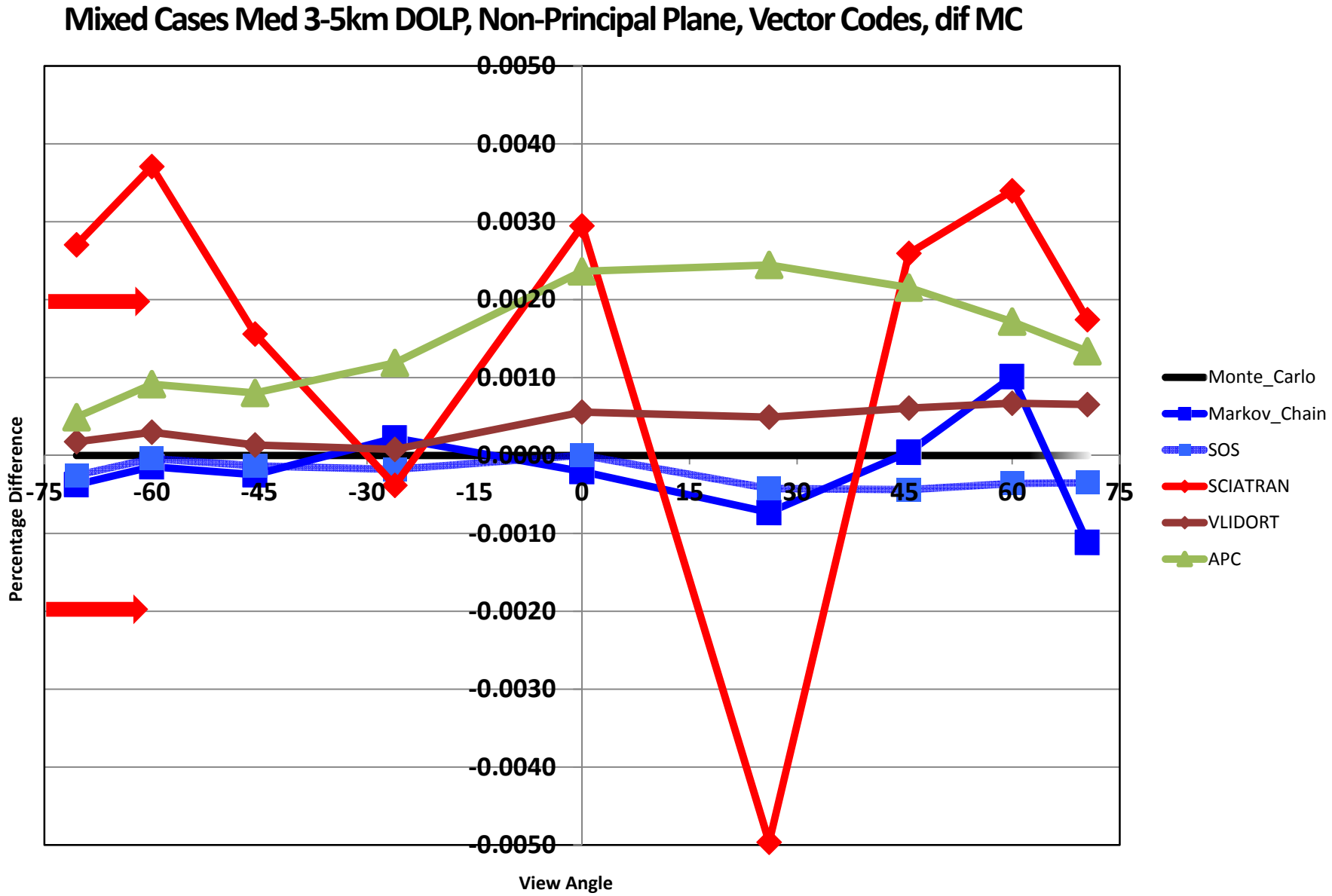
- Every model as a reference
- Clear view of non correlation
- No need for multiple plots

Radiance

$$\frac{Test\,Value - Ref.Value}{0.01 * Ref.Value}$$

DOLP

$$\frac{Test\,Value - Ref.Value}{0.002}$$

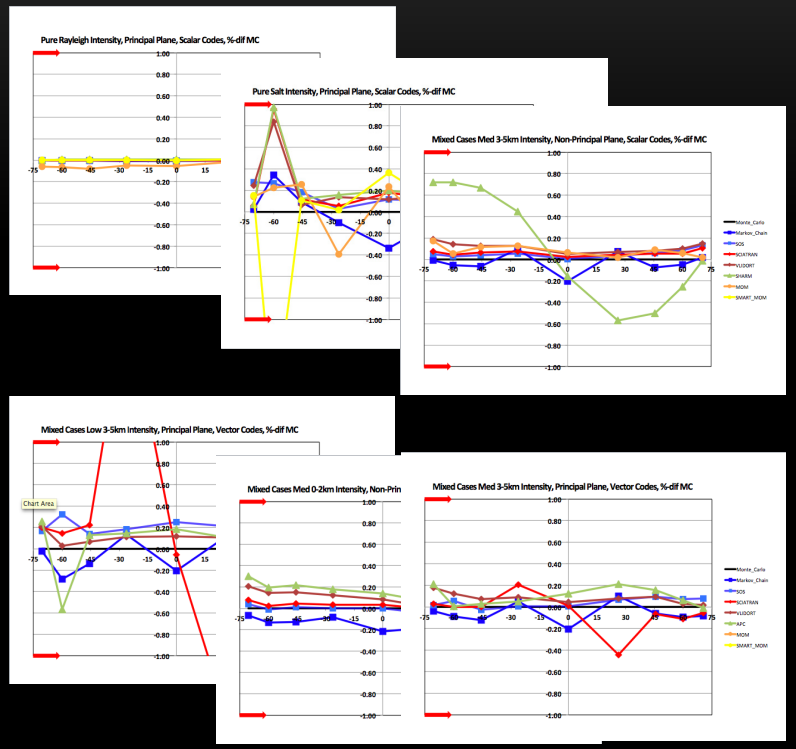

Mixed Cases Med 3-5km DOLP, Non-Principal Plane, Vector Codes, dif MC
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
-0.0010
-0.0020
-0.0030
-0.0040
-0.0050
-75
-60
-45
-30
-15
0
15
30
45
60
75
Percentage Difference
View Angle
Monte_Carlo
Markov_Chain
SOS
SCIATRAN
VLIDORT
APC

Results

- **Scalar goal:** Do radiances agree within 1%?
  - No: 70% within goals, 90% without SHARM
- **Vector goals:** Do radiances agree within 1%?
  - No: 70% within goals

  Do DOLPs agree within 0.002?
  No: 35% agreement

… but it is work in progress!



A Special Thanks

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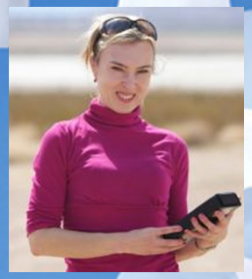

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STEPHEN BECHTEL FUND

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Center for Excellence in Science and Mathematics Education

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Grant No.
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CSU The California State University